NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

February 5, 2014

Group Chairman's Factual Report

STRUCTURES

DCA13MA120

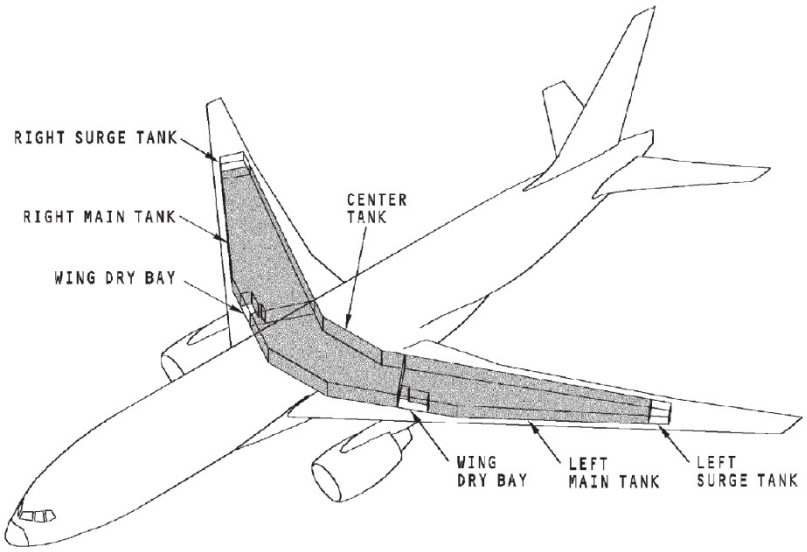
Addendum 1

Boeing Fuel Tank Report

Addendum to Structures Factual Report- Fuel Tanks

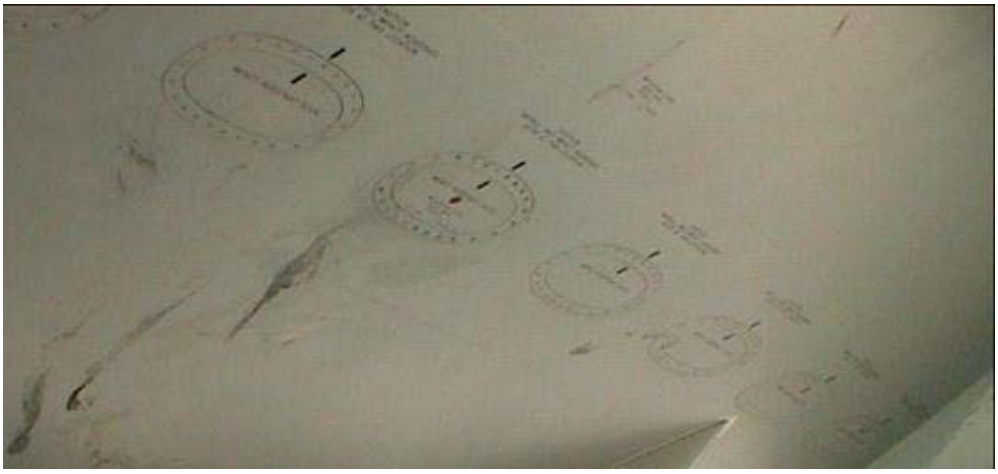
Introduction

On the 777-200, the wing box structure acts an integral fuel cell and carries the entire mission fuel for the airplane. The incident airplane featured three (3) individual fuel tanks; one in each outboard wing, between Rib 8 (Wing Station 387.0) and Rib 32 (Wing Station 1021.5) and a center fuel tank, located between right-hand and left-hand Rib 8 (including the wing center section, within the fuselage contour). The tanks are isolated from one another via structural fuel barriers (tank end ribs), with cross-tank communication provided by the airplane fuel system. To meet the requirements of 14CFR 25.963(d), the center fuel tank within the fuselage contour is protected from scraping on the ground by the engines and, in the case of engine departure, the airplane keel beam structure. Attached to the fuel tank boundary, at the rear spar, are the main landing gear attachment fittings and, along the lower wing skin and front spar, are the engine attachment fittings.



777-200 Fuel Tank Arrangement

In order to provide access to the inside of the wing box/fuel tank for manufacturing, as well as in-service maintenance, fuel tank doors are installed down the middle of the wing lower panel. These fuel tank access doors are designed to be compliant with 14CFR 25.963(e). Per 25.963(e)(1), doors in the region likely to be struck by tire fragments, and/or debris (low energy engine debris or other debris), are designed and tested to withstand those impact energy levels. For the 777-200, these impact resistant doors are located between the side-of-body and Rib 18 (Wing Station 652.0).



Typical Wing Lower Panel Fuel Access Door Installation

Right Wing Fuel Tanks

As noted in the main body of the Structures Factual Report, the right hand wing was found fully attached to the wing center section at the side-of-body rib, and there were no signs of any fuel leakage at the side-of-body joint. Within the fuel tank boundaries, the upper and lower wing skin panels, the front and rear spars, the spar-to-skin connections and the discrete attachments of the main landing gear and engine support fittings to the wing box were examined in detail. Other than the leak noted emanating from the fuel tank access door located at approximately Wing Station 425, which will be discussed in detail below, there were no signs of fuel leaking from the right main or center fuel tanks.

Between Ribs 9 and 10, at approximately Wing Station 425, a running fuel leak was discovered to be emanating from the inboard corner of the interface between the access door and the lower skin. The rate at which fuel was observed to be leaking was not sufficient to cause the fuel to drip onto the ground, but rather run due to surface tension along the wing lower surface to a point where the wing was resting on the ground. Examination of the fuel tank door and skin at the leak location revealed that door had been pushed inward by an externally applied force (there were indications of scraping along the lower wing skin that ran across the door corner). As noted before, the door installation in this location is designed per the requirements of 25.963(e)(1) to withstand the energies associated with a piece of thrown tire tread or low engine debris.

Right Wing Fuel Tank Leak @ WS 425 Tank Access Door

Left Wing Fuel Tanks

As noted in the main body of the Structures Factual Report, the left hand wing was found fully attached to the wing center section at the side-of-body rib, and there were no signs of any fuel leakage at the side-of-body joint. Within the fuel tank boundaries, the upper and lower wing skin panels, the front and rear spars, the spar-to-skin connections and the discrete attachments of the main landing gear and engine support fittings to the wing box were examined in detail. Other than the leak noted emanating from the fuel tank access door located at approximately Wing Station 400, which will be discussed in detail below, there were no signs of fuel leaking from the left main or center fuel tanks.

Between Ribs 8 and 9, at approximately Wing Station 400, a running fuel leak was discovered to be emanating from the inboard corner of the interface between the access door and the lower skin. The rate at which fuel was observed to be leaking was not sufficient to cause the fuel to drip onto the ground, but rather run due to surface tension along the wing lower surface to a point where the wing was resting on the ground. Just outboard of the fuel leak location, between Ribs 9 and 10, at approximately Wing Station 425, the fuel tank access door was found with much more damage, with a visible gap between the wing skin and the door. No fuel was observed to be leaking from this location, but it is not known if the fuel tank levels of the airplane and airplane attitude were such that no fuel was spilled or if a fuel leak did occur and sufficient quantities spilled to uncover this location. Examinations of the fuel tank door and skin at the both locations revealed that door had been pushed inward by an externally applied force (there were indications of scraping along the lower wing skin that ran across the doors in both locations). As noted before, the door installations in these location are designed per the requirements of 25.963(e)(1) to withstand the energies associated with a piece of thrown tire tread or low speed engine debris.

Left Wing Tank Leak @ WS 400 Tank Access Door

Damage @ WS 425 Tank Access Door

Wing Center Section Fuel Tank

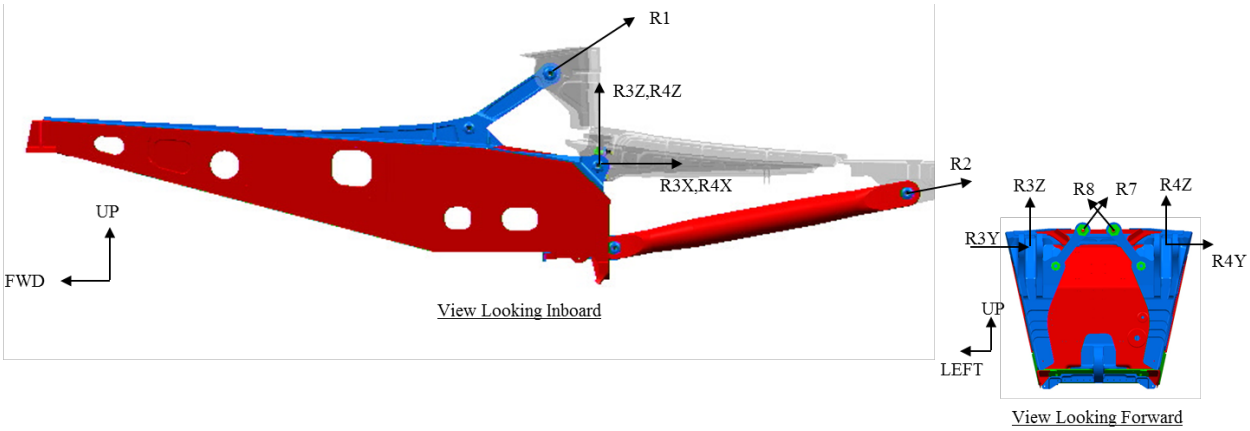
During the initial visit to the incident airplane, access to the wing center section was somewhat limited. Cargo in the forward cargo hold didn't allow a detailed inspection of the front spar (although it was noted during an evaluation of the forward cargo hold that the front spar appeared intact and there were no signs of fire in the hold), the resting position of the airplane on the ground didn't allow for examination of the wing lower surface and the cabin investigation prevented a thorough examination of the wing upper surface and floor support structure.

Observations were able to be made that indicated the ground underneath the airplane was not saturated with jet fuel, nor were there signs of fire damage or soot in the area of the wing center section, despite its proximity to the fuselage fire, just forward of the wing. The position of the airplane did allow for a detailed inspection of the center section rear spar and no signs of structural failure, fuel leakage, soot, or fire damage were observed. During the effort to move the airplane off of the runway, the lower skin of the wing center section was examined from a distance and the skin was observed to be intact with the flanges of the keel beam chords still attached, leaving the fuel tank boundary undisturbed.

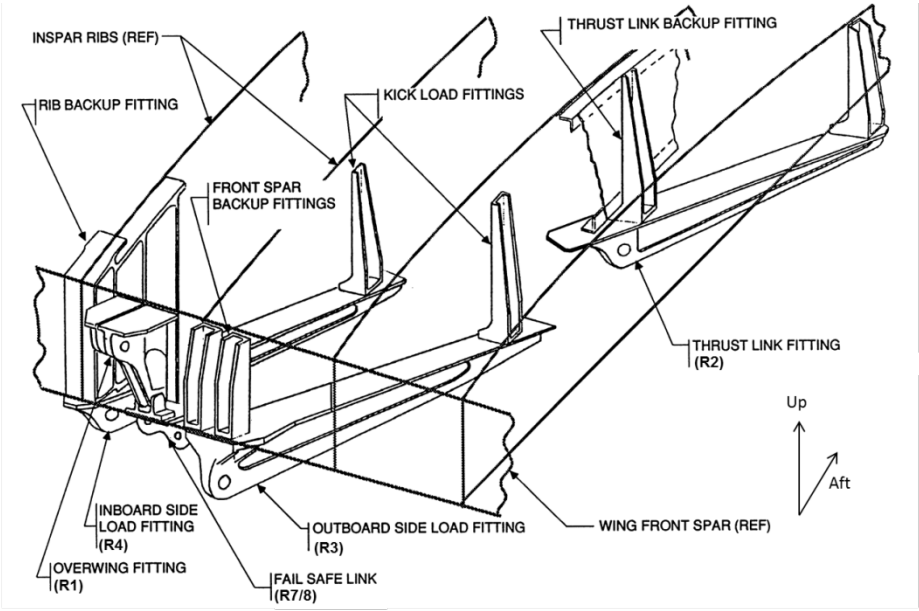
A return visit to the aircraft in August, 2013 allowed for a more complete inspection of the remaining wing center section fuel tank details. The front spar was examined thoroughly and no signs of structural damage, fuel leak or fire were found. As noted in the main body of the Factual Report, the wing center section upper panel and overwing floor beams were examined by removing selected floor panels and cutting inspection holes in floor panels in other locations where complete panel removal was not practical or safe. No signs of structural damage, fuel leak or fire were found. During the final phase of the aircraft recovery effort, the wing center section was lifted off of the ground, allowing for an up close examination of the lower skin. It was confirmed that the lower skin remained intact and the keel beam chords remained attached to the skin.

Engine Strut-to-Wing Attachments- Overview

The attachment of the 777 engines to the wing fuel tanks is controlled by a series of fuse pins, which connect the strut to the wing fittings. These fuse pins are designed to fail under a prescribed load, in the case of an event that overloads the strut-to-wing attachment beyond design ultimate load, thus protecting the wing fuel tank structure. The wing fittings and their local attachments to the wing are sized with an additional safety factor to insure that the fuse pin is always the weak link in the strut-to-wing joint.



777 Strut-To-Wing Attachments (L/H Side Shown)



777 Strut-to-Wing Fittings (L/H Side Shown)

Engine Strut-to-Wing Attachments- Fuel Tank Findings

As noted in the main body of the Structures Factual Report, the examination of the left hand wing indicated that there were no signs of structural overload to the wing attachment fittings or the wing box. The R2, R3 and R4 fuse pins were all found failed, with sheared pin sections remaining in the fitting lugs. The R1 overwing exhibited negligible damage, with the strut upper link still attached, indicating failure occurred at the engine end of the upper strut. The R7 & R8 side load link attachment fittings exhibited negligible damage, with the side load links still attached. At all locations, the wing fuel tank boundary was found to be undisturbed and structurally intact.

L/H Wing- R1 Fitting w/ Intact Upper Strut

L/H Wing- R2 Fitting w/ Fused Pin

L/H Wing- R3&R4 Fittings w/ Fused Pins

L/H Wing- R7/R8 Attachment

As noted in the main body of the Structures Factual Report, the examination of the right hand wing indicated that there were no signs of structural overload to the R1, R2, R4 and R7/8 attachment fittings or the wing box. The R2 and R4 fuse pins were found failed, with sheared pin sections remaining in the fitting lugs. The R1 overwing exhibited negligible damage, with a portion of the strut upper link still attached, indicating failure in the strut general cross-section. The R7 & R8 side load link attachment fittings exhibited negligible damage, with the inboard side load links still attached. The R4 fitting was found with a fractured lug, but there was no observable damage to the connection between the fitting and the lower wing skin. This damage was consistent with the R3 fitting failure occurring after all other connections were fused, resulting in large lateral loads acting on the R3 fitting lug, during the airplane ground slide. At all locations, the wing fuel tank boundary was found to be undisturbed and structurally intact.

R/H Wing- R1 Fitting w/ Upper Strut Segment

R/H Wing- R2 Fitting w/ Fused Pin

R/H Wing- R7/8 Attachment

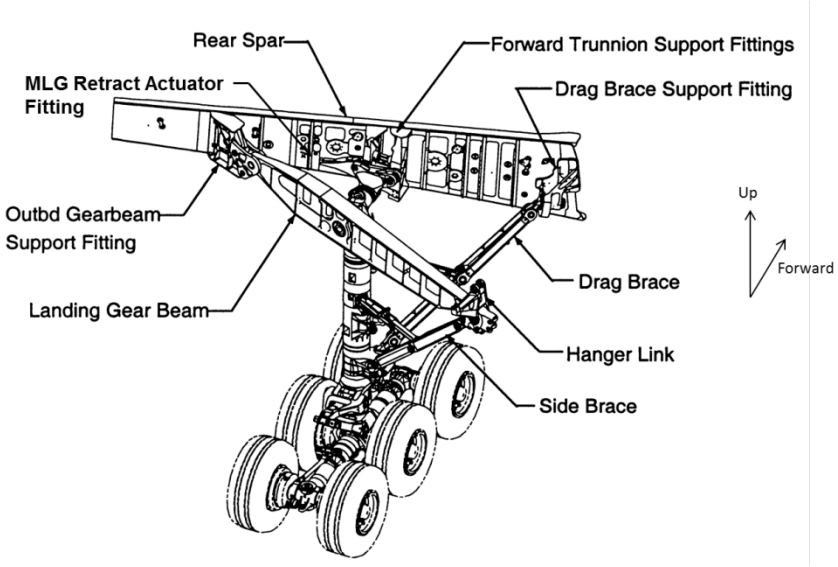
R/H Wing- R4 Fitting w/ Fused Pin

R/H Wing- R3 Fitting w/ Failed Lug

Main Landing Gear Attachments- Overview

The 777 Main Landing Gear attachments to the wing rear spar are controlled by a series of fuse pins, which connect the landing gear to the wing fittings. Much like the engine attachments, these fuse pins are designed to fail under a prescribed load, in the case of a landing gear breakaway event, thus protecting the wing fuel tank structure. The wing fittings and their local attachments to the wing are sized with an additional safety factor to insure that the fuse pin is always the weak link in the joint.

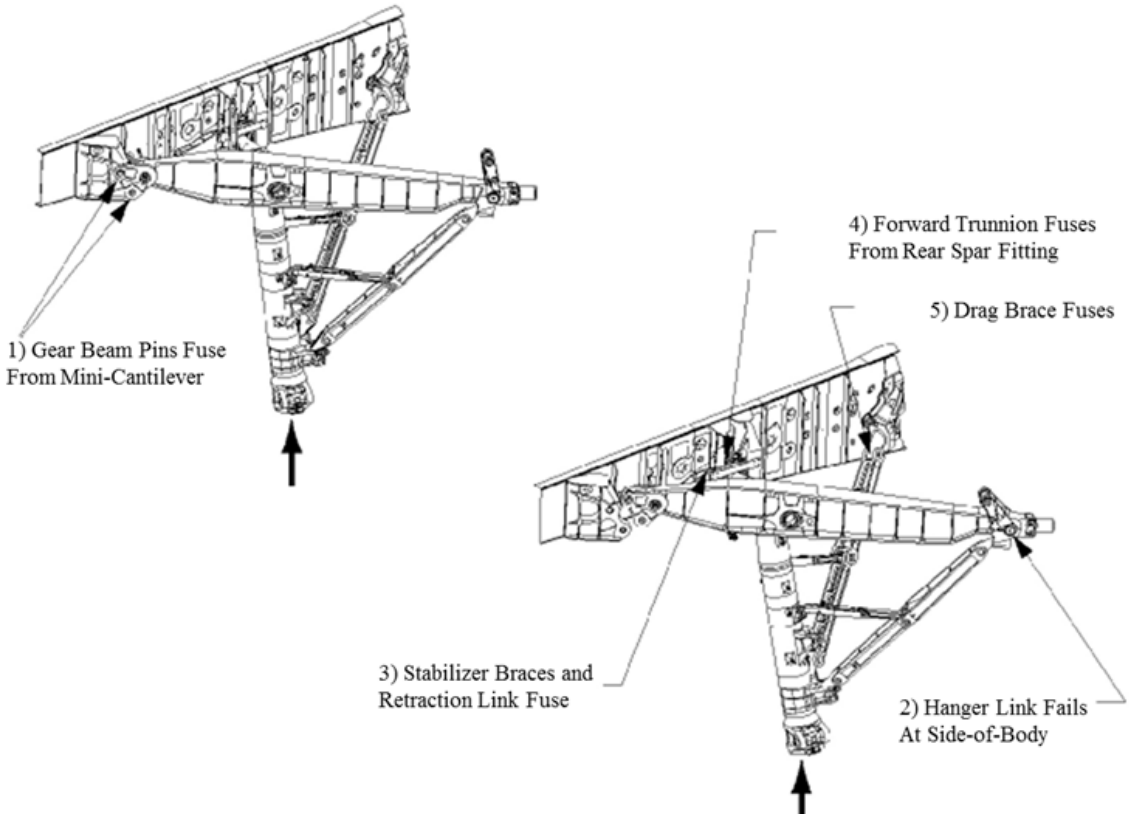
Per regulatory requirements, the main landing gear attachments are designed such that, in the case of a gear breakaway event, resulting in excessive upward and/or aft acting loads, the landing gear will separate from the aircraft without rupture of the fuel tank.



777 Main Landing Gear Configuration

Main Landing Gear Attachments- Breakaway Sequence

In the event of a main landing gear breakaway event, the 777 airplane main landing gear is designed to separate according to a prescribed sequence. The sequence for a vertically-dominated event differs from a drag-dominated event. The observations made at the accident scene, as well as the evidence gathered from the airplane, indicate that this was a breakaway event dominated by a vertical gear overload. The relatively low forward velocity of the aircraft, combined with the high sink rate and angle of attack also support this finding. Both the left hand and right hand landing gears exhibited similar damage and the physical evidence indicated that the failures occurred per the designed scenario.



777 Vertically Dominated Main Landing Gear Breakaway Scenario

Main Landing Gear Attachments- Findings

The main landing gear attached to the wing fuel tank at four locations; the drag brace support fitting, the forward trunnion support fitting, the gear retract actuator fitting and the outboard gear beam support fitting. At each of these locations, the damage was limited to the fuse pins (at the drag brace support, the drag strut fused before the pin failed, but the support fitting and rear spar were protected) and the wing fuel tank boundaries were found undamaged and structurally intact.

Outbd End of L/H MLG Beam w/ Failed Fuse Fuse Pins (R/H similar)

L/H Gear Retract Actuator Ftg w/ Failed Fuse Pin (R/H similar)

L/H Forward Trunnion Attachment Failure w/ Fused Lower Housing and Intact Upper Strap (R/H similar)

Lower Strap R/H Drag Brace Fitting w/ Spindle Still on Aircraft (L/H similar)

Summary

In summary, the observations of the wreckage indicated that the main landing gears separated as designed for a vertical overload event, the engine separation occurred per design, and no ruptures in any fuel tank structure were observed. The fuel leaks that did occur did not appear to have any involvement in the post-crash fire and originated at maintenance access doors in the wings, which appeared to have been impacted by foreign objects during the crash sequence.